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REVIEW OF BUBBLE CHAMBERS

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ABSTRACT

This review of bubble chamber technology is done by looking at current experiments being performed and by looking at proposals for future experiments.

INTRODUCTION

This paper will be divided into the six categories used as headings in Table I. Table I is an approximate list of bubble chambers which should be operating in 1973. It is interesting to note that in 1970 there were about sixteen operating bubble chambers of which nine have died. However, as can be seen from Table I, by 1973 there will be eleven new operating bubble chambers for a total of eighteen.

Table I. Operating Chambers
As Of July 1, 1973

Conventional	<30GeV/c	82" SLAC, 2m CERN, 80" BNL, 1m Dubna, 12' ANL, 1m Japan, BEBC CERN, 7' BNL
Neutrals	<30GeV/c	Gargamelle CERN, 1.5m Rutherford, (80" BNL)
Rapid Cycling-Triggered	<30GeV/c	40" SLAC, 15" SLAC
High Energy-Hybrid	<500GeV/c	30" NAL
High Energy Conventional	<500GeV/c	Marabelle Serpukhov, 2m H_2 Serpukhov, 2m C_3H_8 Serpukhov, (30" NAL), 15' NAL
Special Purpose	<30GeV/c	Hybuc CERN

CONVENTIONAL CHAMBERS

The four chambers listed in Table II produce the majority of film. Some of the interesting figures associated with these chambers show that experimental proposals average 460,000 pictures per experiment, and 13,500,000 pictures will be taken next year for approximately thirty experiments. The emphasis in these proposals is for K^- mesons between 4 and 9GeV/c. The CERN 2m and BNL 80-inch operates in a double-pulse mode and the SLAC 82-inch operates at two per second.

Table II. Conventional Chambers <30GeV/c*

Chamber	82" SLAC	2m CERN	80" BNL	12' ANL
Proposed+	$6x10^6$	$9.6x10^6$	$3.2x10^6$	$2.6x10^6$
Number of Experiments	12	23	10	5
<Photos per Experiment>	$.5x10^6$	$.42x10^6$	$.32x10^6$	$.52x10^6$
Expect per Year	$5x10^6$	$5x10^6$	$1.5x10^{6}$†	$2x10^6$

*Not a complete list (e.g. U.S.S.R. not included).

+Lists of proposals can be obtained from the various laboratories.

†See Table III also.

NEUTRAL DETECTION

The near future should see the beginning of experiments with track-sensitive targets. Figure 1 is a picture of a track-sensitive target in the 1.5 meter Rutherford Chamber. The target contained hydrogen and the chamber contained a 45 mole percent neon-hydrogen mixture. The target was 4.5 centimeters deep and the length of the chamber.

Table III shows that there is considerable interest in experiments with neutral detection. The emphasis in these proposals is to study $2\pi^\circ$ channels in π^+, π^-, K^- and $\bar{p}$ interactions.

Table III:* Neutral Detection+
<30GeV/c

Chamber	1.5m TST Rutherford	Gargamelle CERN	80" TST BNL
Proposed†	1.3×10^6	$.7 \times 10^6$	3.6×10^6
Number of Experiments	3	2	8
<Photo per Experiment>	$.43 \times 10^6$	$.35 \times 10^6$	$.45 \times 10^6$

*Note this is an approximate table since proposals frequently change.

+Not a complete list (e.g. U.S.S.R. not included).

†Lists of proposals can be obtained from the various laboratories.

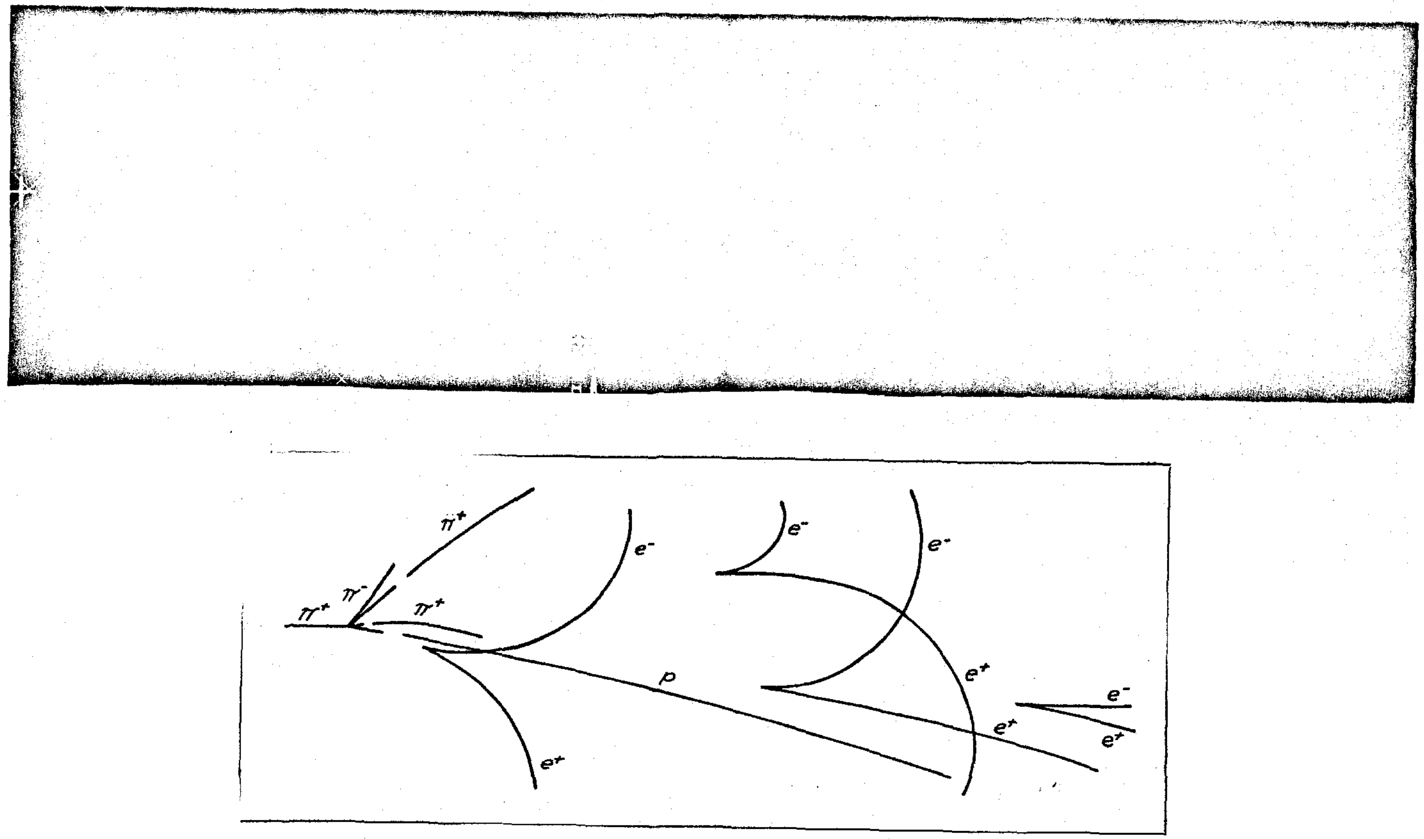

Figure 1. Picture from Rutherford Laboratory 1.5 Meter Chamber with internal track-sensitive target.

RAPID CYCLING-TRIGGERED

Presently, operation of rapid cycling bubble chambers is being successfully done at SLAC. The 40-inch chamber operates up to ten pulses per second (36,000/hr) and the 15-inch should operate at sixty pulses per second.

Figure 2 shows the Cal Tech-Berkeley experimental setup and data for the 40-inch chamber experiment. The experiment was 14GeV/c

$$\pi^- + p \rightarrow \pi^- + X$$

where the downstream spectrometer analyzes the fast forward π^-. Figure 2b shows the mass spectrum calculated on-line from the spectrometer. Figure 2c shows the time necessary to do the on-line mass calculation and the time where the lights (to take a photograph) are flashed. It is clear that the apparatus can calculate the missing mass to the outgoing π^- and decide whether or not to take the picture. In this manner, any mass range can be selected. Figures 2d and 2e show the missing mass for events with a missing neutron or π° calculated using both the chamber and spectrometer information. There is a very clean separation of single missing neutral events from multiple neutrals missing (the arrows on the figures indicate two missing neutrals threshold).

The momentum transfer acceptance from incident π^- to outgoing π^- is good for $0.02 < t_{\pi^-\pi^-} < 0.6\,(\mathrm{GeV/c})^2$. Mass acceptance is good up to 3GeV.

Figure 3 is an engineering detail for the SLAC 15-inch Bubble Chamber. As can be seen, the solid angle available is 288° in the azimuthal plane and 18.5° in the equitoral plane. The magnetic field will be 16 kilogauss (superconducting magnet).

Figure 4 shows an experimental setup for a proposed experiment for Purdue, Indiana and Vanderbilt. The experiment will be

$$\pi^{\pm} + p \rightarrow n + X_{\circ}^{++}$$

where the downstream detectors will trigger the flash when there is a forward n.

With such rapid cycling bubble chambers, experimenters can look at order of magnitude smaller cross sections compared to conventional bubble chamber experiments.

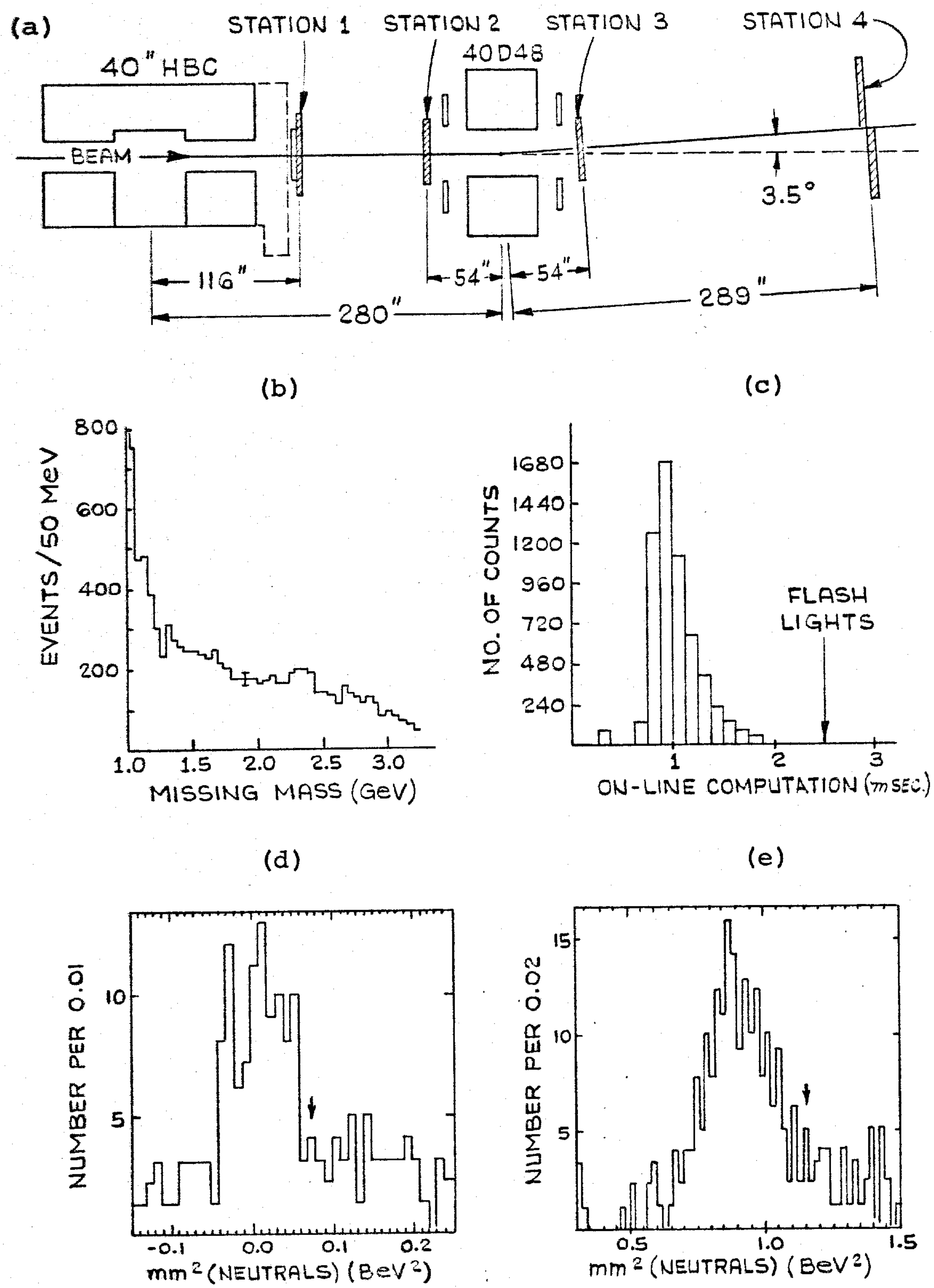

Figure 2. Experimental setup and data from Cal Tech-Berkeley experiment in SLAC 40" Bubble Chamber.

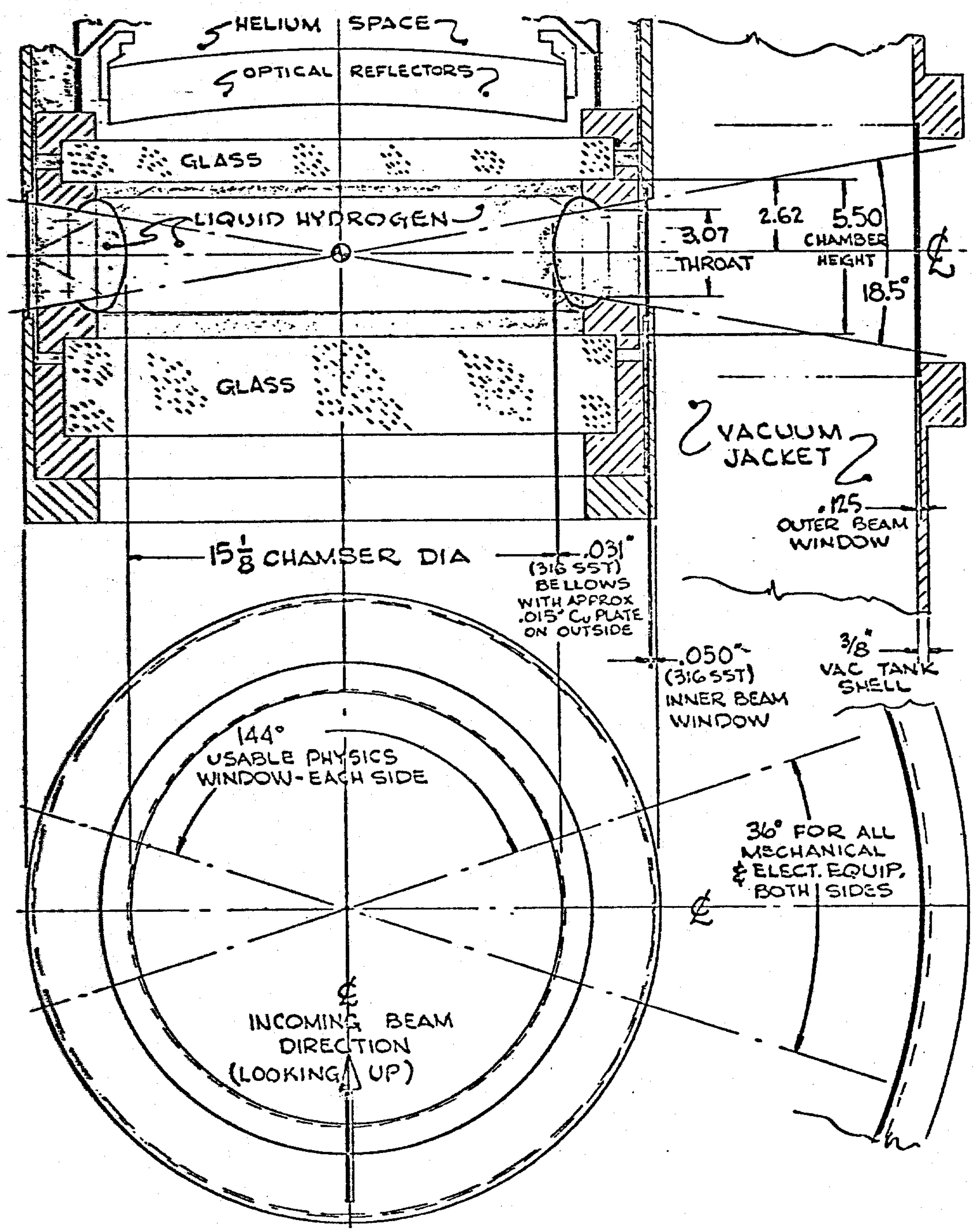

Figure 3. Engineering Details for SLAC 15-inch Rapid Cycling Bubble Chamber.

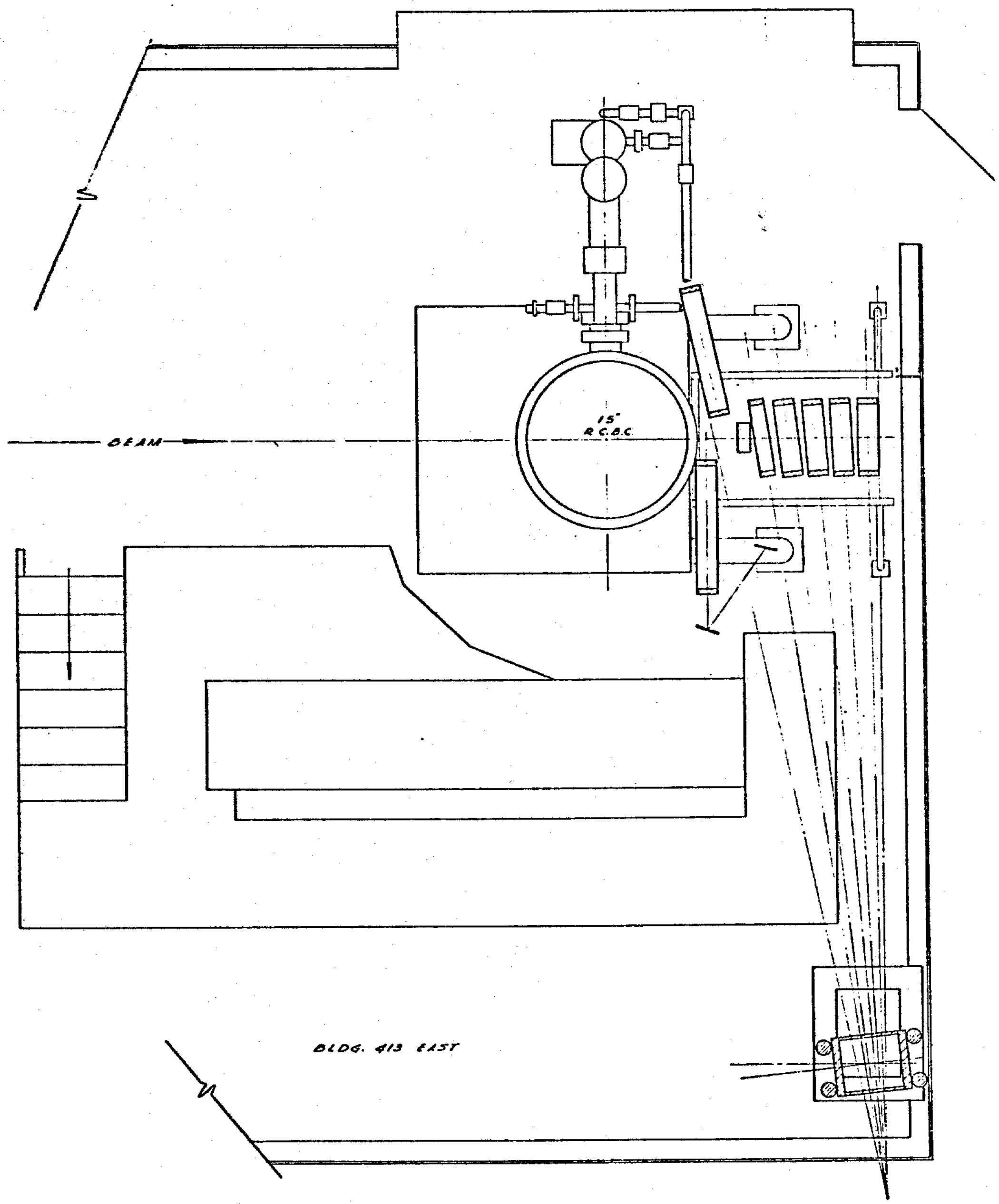

Figure 4. Experimental setup for Purdue, Indiana, and Vanderbilt experiment in the SLAC 15-inch Rapid Cycling Bubble Chamber.

HIGH ENERGY-HYBRID

Figure 5 shows the experimental setup for Experiment 2I at NAL. The universities involved in this experiment are Michigan State, Iowa State, Maryland, Purdue, Wisconsin, Duke, Notre Dame, Toronto and Argonne National Laboratory. These experimenters have been approved for

200,000 pictures	$p+p$	100-400GeV/c
170,000 pictures	π^-+p	100-300GeV/c
80,000 pictures	π^++p	100-300GeV/c

In this particular setup, the downstream optical spark chambers with the bubble chamber magnetic field are used to measure tracks with momenta greater than 20GeV/c and the 30-inch Bubble Chamber is used to measure tracks with momenta less than 20GeV/c.

Another experiment at NAL with the 30-inch Bubble Chamber, upstream beam tagging using proportional wire chambers and a Cerenkov counter, and downstream proportional wire chambers is approved for tests. This experiment (#154) is a collaboration of MIT, Brown, Illinois, IIT, Indiana, Johns Hopkins, Rutgers-Stevens, Tennessee - Oak Ridge, and Yale-NAL to do a general survey of high energy interactions between 100-500GeV/c and in particular, look at diffraction dissociation of the target.

HIGH ENERGY CONVENTIONAL

The chambers at Serpukhov are already taking pictures and in fact, there is a recent preprint[1] giving charged particle multiplicities for 50 and 69GeV/c p+p interactions in Marabelle.

There are eight approved "bare" chamber proposals at NAL for the 30-inch Bubble Chamber. They are:

50,000 pictures	$p+p$		ANL
50,000 pictures	$p+p$	low energy	Rochester
50,000 pictures	$p+p$	medium energy	Michigan
50,000 pictures	$p+p$	high energy	NAL, UCLA
50,000 pictures	π^-+p	low energy	CERN
50,000 pictures	π^-+p	medium energy	BNL
50,000 pictures	π^-+p	high energy	NAL-UC-LBL
50,000 pictures	π^++p		Davis

These experiments should start soon.

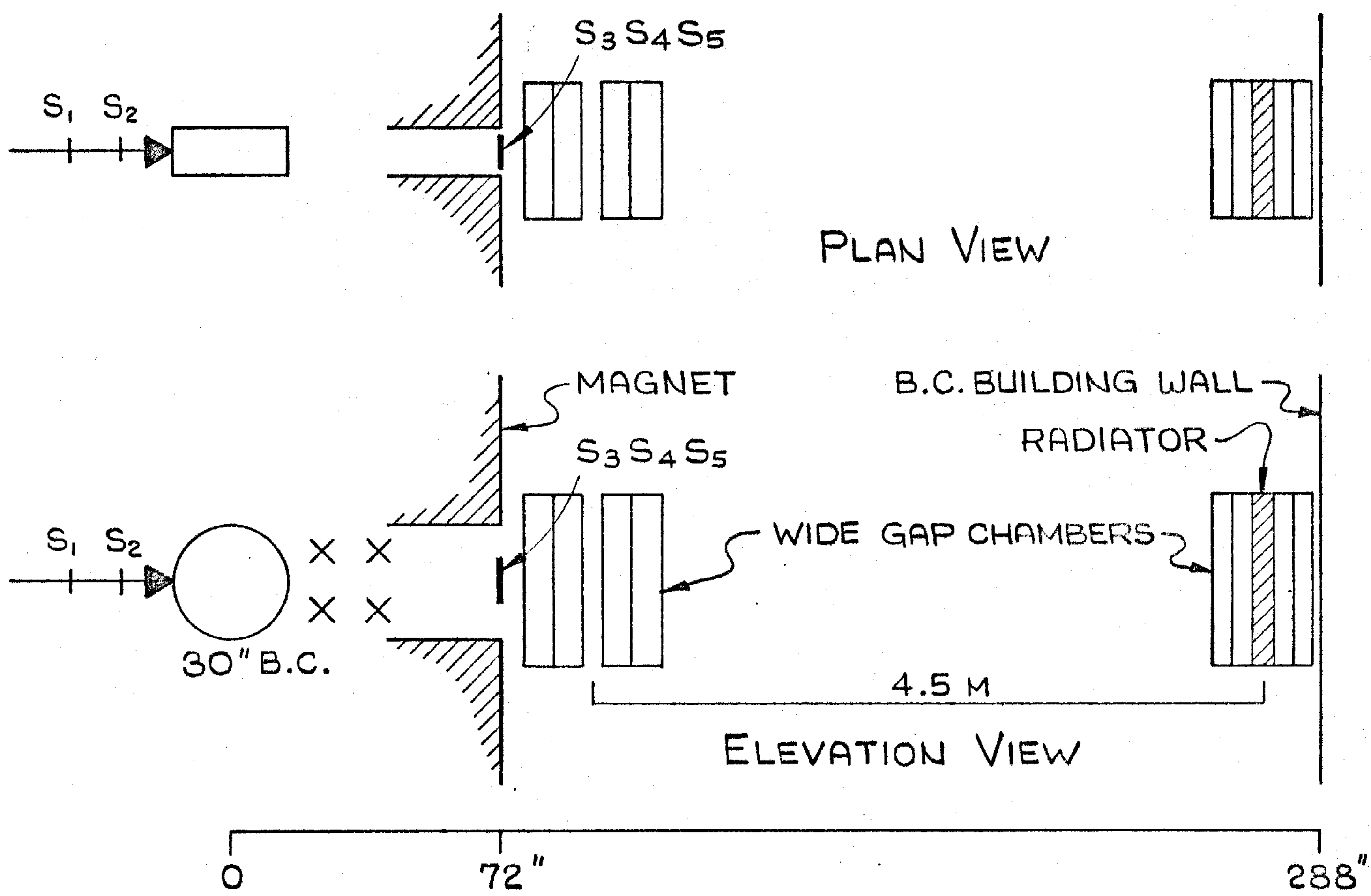

Figure 5. Experimental setup for Experiment 2I at NAL.

The NAL 15-foot Bubble Chamber[2] (see Figure 6) is still on schedule and should start doing physics in January 1973. It will be able to operate with hydrogen-neon mixtures. Studies[3] at the NAL Aspen Summer Programs indicate that four constraint physics will be possible in the 15-foot chamber and that hydrogen-neon mixtures will be important for detecting π° mesons.

SPECIAL PURPOSE

The single special purpose bubble chamber at present is HYBUC[4] at CERN. This chamber is built with a high magnetic field (110 Kilogauss) to measure hyperon magnetic moments. The chamber is 32cm long and 12.8cm diameter with an axial magnetic field. It will possibly have the capability of multipulsing up to twenty times per accelerator pulse.

The first experiment to measure the Σ^+ magnetic moment is being performed by the builders of the chamber, Max Planck Institute, Munich, Niels Bohr Institute, Copenhagen and Vanderbilt University.

CONCLUSION

Even though this is a conference on mesons, it should be noted that soon many important physics results will come from exposures of the ANL 12-foot, CERN Gargamelle, NAL 15-foot and BNL 7-foot to neutrinos and antineutrinos. Similarly, because of the fast cycling rate of the 40-inch SLAC Bubble Chamber, there will soon be results from muon interactions in hydrogen.

The conclusions from the study for the first part of this paper are that the number of photos per year will most likely continue to increase since there are not only more chambers but most are multipulsing and the number of pulses of bubble chambers per year will increase at a greater rate. With chambers such as the SLAC 40-inch and 15-inch, it will be normal to have experiments with many million pulses.

While the large chambers will certainly be important for neutrino physics, they will also be important to hadron physics for high energies. It will also be important to have track-sensitive targets for high energy large bubble chambers to detect neutral particles.

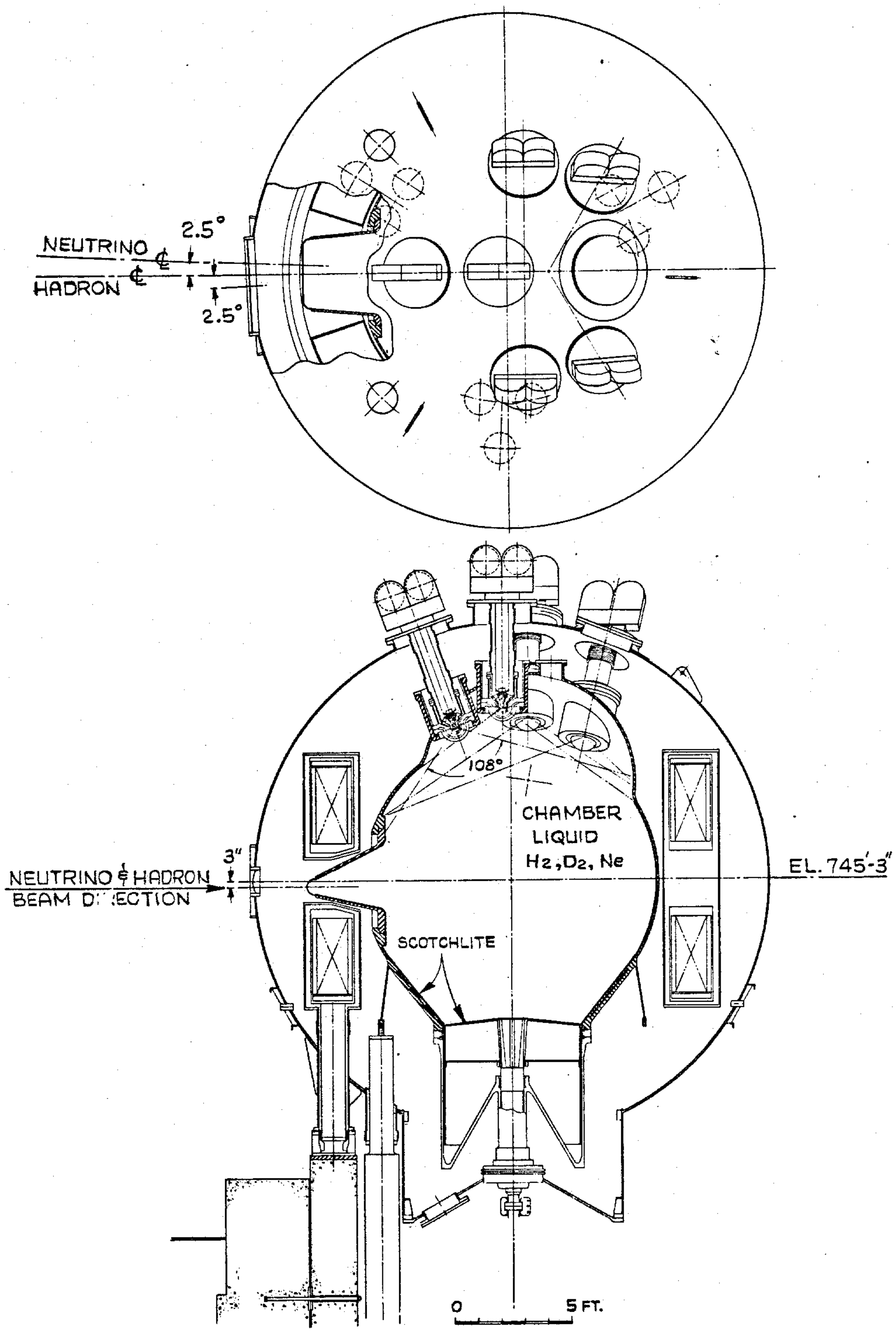

Figure 6. 15-foot NAL Bubble Chamber

[1] Soviet-French Collaboration, 4th Int. Conf. High Energy Coll., "Preliminary Determination of the Average Particle Multiplicity and of the Topological Cross Sections in 50GeV/c and 69GeV/c PP Interactions", (April 1972) (To be published).

[2] F.R. Huson, NAL, "Design of Optics for the NAL 15-foot Chamber", (April 1971).

[3] NAL Summer Study Bubble Chambers and Neutrino Beam, Vol. 1, (1968).
NAL Summer Study Bubble Chambers, Vol. 2, (1969).

[4] CERN Courier, No. 11, Vol. 10, p. 353, (Nov. 1970).
CERN Courier, No. 1, Vol. 11, p. 15, (Jan. 1971).
CERN Courier, No. 3, Vol. 11, p. 65, (Mar. 1971).
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